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Remote Handling Equipment for a High-Level Waste Waste Package Closure System

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Remote Handling Equipment for a High-Level Waste
Waste Package Closure System

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Abstract – *High-level waste will be placed in sealed waste packages inside a shielded closure cell. The Idaho National Laboratory (INL) has designed a system for closing the waste packages including all cell interior equipment and support systems. This paper discusses the material handling aspects of the equipment used and operations that will take place as part of the waste package closure operations. Prior to construction, the cell and support system will be assembled in a full-scale mockup at INL.*

I. BACKGROUND

Nuclear reactors for the generation of energy and conducting research have been in existence for more than 50 years. Spent nuclear fuel (SNF) and associated high-level waste (HLW) have accumulated in temporary storage as a result of these activities. Locations for a geological repository have been evaluated for permanent disposal of the SNF and HLW.

During repository operations, commercial and government-owned SNF and HLW will be loaded into casks and shipped to a repository. Materials will be transferred from the casks into waste packages (WPs), closed, and placed into an underground disposal site. Closure operations include placing lids onto the WP and welding the lids onto the container, filling the inner container with an inert gas, performing nondestructive examinations on welds, conducting stress mitigation and material handling. All WP loading and closure operations will be performed in hot cells.

To fulfill this need, INL has been contracted to design, build, and demonstrate a full-scale mockup of the proposed closure cell. The INL system mockup may also be transferred to the contractor and used for operator training.

II. OPERATIONAL AND DESIGN ISSUES

There are a number of issues associated with material handling in a closure cell. These issues are tied to the operations that are required for the remote delivery or retrieval of a wide variety of equipment and materials necessary for WP closure or to the support of that closure equipment. The primary output from the closure cell is a correctly sealed and tested WP that may then be placed in a repository.

A typical closure cell may be 30 ft wide × 40 ft long × 29 ft high (inside dimensions). The layout of the cell is focused around an engineered hole in the floor, providing access to the WP containing radioactive material. The top of the WP is positioned within this hole by facility operations within a predetermined tolerance range. An elevation view of a closure cell is shown in Figure 1.

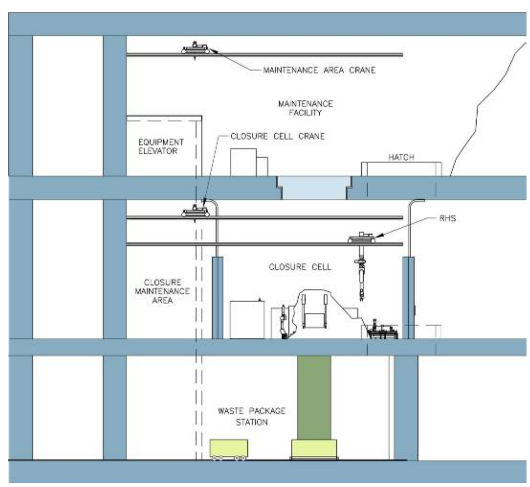

Fig. 1. An elevation view of a typical closure cell.

All material handling operations are performed remotely because of the high radiation fields expected from the WP. This includes all WP closure, maintenance, repair, and replacement operations.[a] Although not described in detail in this paper, the WP is seal welded and inspected by two robotic manipulators mounted on a carriage assembly around the access hole. In addition, the closure cell includes numerous strategically placed lights and cameras. Design for remote operations makes operations inside the cell as cost effective and productive as possible.

III. CLOSURE CELL DESCRIPTION, CAPABILITIES, AND PERFORMANCE

The closure cell handling equipment is designed, built, and installed using standard off-the-shelf equipment to the maximum extent possible. This approach allows components and component assemblies to be readily exchanged, minimizing downtime. A modular equipment philosophy is also being adopted to assist in maintenance and repair operations. Using a modular approach ensures that components and systems can be designed, fabricated, and installed with a minimum of interface and operational readiness problems. Repair and replacement of equipment is also made easier because of modularity.

IV. PRIMARY COMPONENTS AND SUBASSEMBLIES

Closure cell remote handling systems (RHSs) are composed of a variety of equipment and systems located both within the closure cell environment and outside the closure cell in an adjacent support area. Within the closure cell are the RHS, master-slave manipulators (MSMs) and the overhead bridge crane (OHC). In the closure cell support area is a manually operated overhead crane and a glovebox assembly that contains a materials/equipment transfer cart and an overhead manipulator system, both remotely operated. The operator end of the MSMs is located in the closure operating gallery. Each of these systems will be described in greater detail in subsequent sections. A layout of the closure cell, closure support area, and closure operating gallery is shown in Figure 2.

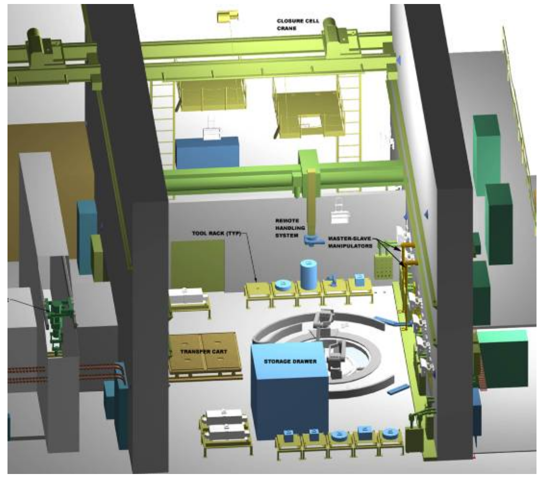

Fig. 2. A preliminary view of the closure cell and associated areas.

IV.A. Closure Cell

IV.A.1. Remote Handling System

The RHS provides for the bulk of equipment and material handling operations within the closure cell. It is an integrated system composed of an overhead bridge assembly (which runs on wall mounted rails), an accompanying trolley assembly, and a telescoping mast assembly. The mast assembly includes a rotary actuator and remote tool interface plate, which provides for rotation of attached tools and equipment. This remote tool interface plate allows the interchange of a variety of tools and equipment needed to perform operations inside the closure cell. Tool plates function by disconnecting into two parts. The main part of the tool plate is attached to the bottom of the telescoping mast. Services (electric, pneumatic, hydraulic, data, etc.) pass through the main part to mating tool plate, which interfaces with tools and equipment used inside the cell. Tool plates mount to the telescoping mast through a compliance device that accommodates mismatched interface surfaces during connection and disconnection operations.[b] A view of the preliminary mast, rotator, compliance device, and tool plate interface are shown in Figure 3.

[a] Manned entry is possible when no waste package is in place. The totally remote aspect is necessary when a waste package is in place in the closure cell and problems arise.

[b] Depending on the positional capability of the final control and machine vision systems, all the axes provided by the compliance device may not be required for this application.

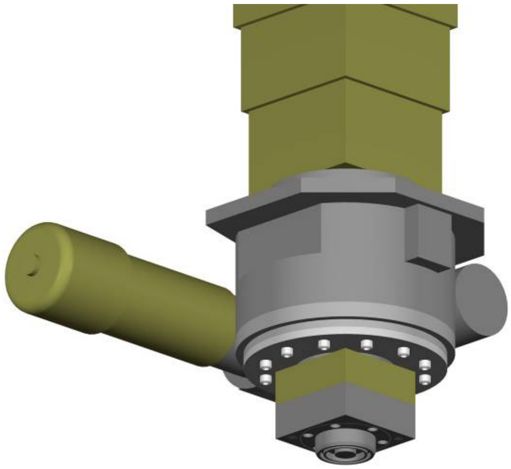

Fig. 3. A view of the mast, rotary, compliance, and tool plate equipment.

Another primary tool that connects at the bottom of the mast is a remotely operated manipulator system. The manipulator is teleoperated and provides for dexterous arm operations within the cell. Operations using the manipulator include such items as assisting with cable and hose management issues, retrieval of dropped tools and equipment, repair and replacement of equipment in the cell, and other necessary operations. This type of manipulator is standard in situations where remote handling operations are required. Experience has shown that they are essential for handling off-normal situations, especially in hazardous environments.

The manipulator itself adds flexibility to the operations with an interchangeable tool interface. A variety of tools may be used with the arm including grippers, hooks, and other special end effectors. The RHS (including the manipulator) is graphically depicted in Figure 4.

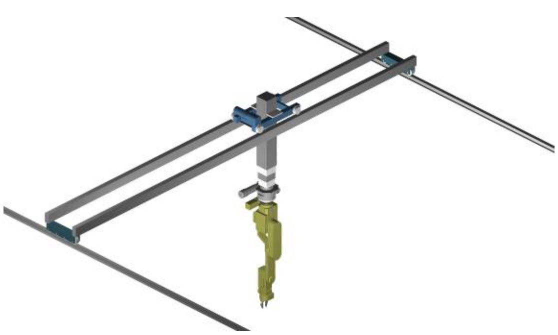

Fig. 4. The RHS consists of a bridge, trolley, mast, and removable manipulator**.**

The RHS is operable in either teleoperated or robotic mode. Teleoperated mode will be used when dealing with an off-normal situation. That is, an event where it is not feasible to operate the system in robotic mode or it is not prudent to do so. An example of this would be to pick up an item that has fallen to the floor. Another example may be to untangle twisted wires, hoses, or cables. Some repair and replacement of items in the cell may also be teleoperated. Teleoperation activities require supplemented vision. Therefore, 3-D stereovision will be used to supplement the operator's vision during teleoperation activities.

Robotic mode provides for preprogrammed and automated moving of the RHS. This mode will be used primarily in pick-and-place applications that are "routine." Preprogramming of the RHS will be performed to assist operations in performing accurate work with repeatability. Programming of the RHS will be supplemented with machine vision technology. This technology provides significantly higher precision and confidence of alignment than a typically instrumented bridge/mast system. Machine vision aids in positioning of the RHS relative to selected objects for placement, connection, and disconnection operations. Ultimately, this will increase productivity and reduce the opportunity for operator error. Each closure cell includes one RHS. The INL mockup includes one RHS unit to confirm the positioning capability and verify material handling tasks.

IV.A.2. Master-Slave Manipulators

The MSMs are teleoperated devices used primarily in hazardous material handling operations. MSMs have a long and distinguished history of success in working in hazardous environments. They, because of their design and physical interface, become an extension of the operator's hands and arms. As such, they provide the ability to perform work precisely and accurately. Although payload is limited compared with other types of manipulators (such as hydraulic or pneumatic assisted), operators can perform tasks requiring finesse, handling of small pieces and parts, and assembly/disassembly of equipment. In this application the MSMs are needed to support the welding robots that are being used to seal weld the WPs. The center line of the access hole, where the MSM must reach, is located 10 feet from the cell interior wall. Because this distance is beyond the nominal work envelope of the MSMs, the MSMs are factory modified to provide reach beyond their normal range of motion. Each closure cell requires one pair of master-slave units. The INL mockup includes one pair for the demonstration.

IV.A.3. Closure Cell Bridge Crane

An overhead bridge crane is installed on a rail system, located near the ceiling of the cells. It will be positioned above the RHS to preclude collisions or unintentional contact between them. A 15-ton crane is specified for this application. This will provide adequate lifting capability for materials and equipment planned for the cells.

The crane is remotely operated from the closure operating gallery control consoles. Control is primarily by video cameras. Limited line of sight viewing is available at the cell windows. The crane includes an upper limit indicator to identify when the crane hook is stowed in its upper position. Supervisory control is implemented to preclude collisions of the crane hook or cable with the RHS as equipment is moved around the cell. At present, the RHS equipment has priority of motion within the cells. Crane motions are designated as secondary. A typical overhead crane is shown in Figure 5.

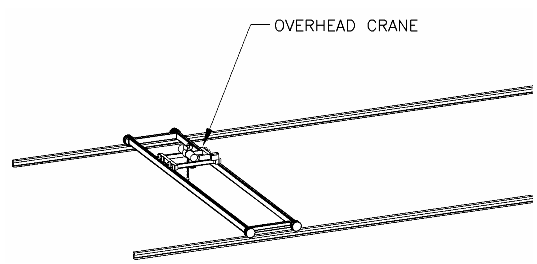

Fig**.** 5**.** The closure cell will have an overhead crane to provide heavy lift support**.**

IV.A.4. Miscellaneous Closure Cell Equipment

Within the closure cell are a number of tools and pieces of equipment that support WP closure operations. The RHS transports this equipment within the cell. Depending on their function, these tools include a remote interface (for the RHS) or hoist rings for the crane or both. A listing of major tools is provided as follows:

- Tool racks — The tool racks provide a storage location for the tools when not in use.
- Storage drawers — The drawer assembly is an engineered cabinet with drawers. It provides for storage of the two lids that are ultimately welded onto the WP. It resembles a large file cabinet. The drawers also provide lay down area for several large, round, and flat pieces of equipment that are used to perform calibrated leak checking of finished welds on the WP.
- Lid lifting tool — This tool provides for movement of the WP lids from the glovebox transfer cart to the storage drawer and then to the WP.
- Evacuation rings — These are large donut shaped rings that are sized and used for leak testing finished welds on the WP. They are installed on the WP by the RHS, perform a calibrated leak test, and are replaced back into the storage drawer.
- Leak detection probe tool — This is a specialized tool used to detect the exact location of leaks in a WP weld. It is transported by the RHS to and from the WP.
- Hardware Device Control Module (HDCM) — This is a portable power/utility unit that interfaces with tools, allowing the RHS to perform other activities while equipment at the WP perform their intended functions. It is placed on the tool either prior to picking the tool up and placing it on the WP or after the tool has been placed on the WP.
- Purge port tool — This is an engineered system that provides for evacuation, and backfilling the inside of the WP, torquing a threaded plug in the inner lid, and leak testing the plug area.
- Stress mitigation tool — This tool is moved to and from the WP by the RHS and is used to reduce tensile stresses in the WP welds.

Other tools and equipment may be necessary to support closure of the WP in the closure cell. The above list represents the main items identified to date. A plan view layout of the closure cell and items discussed above is provided in Figure 6.

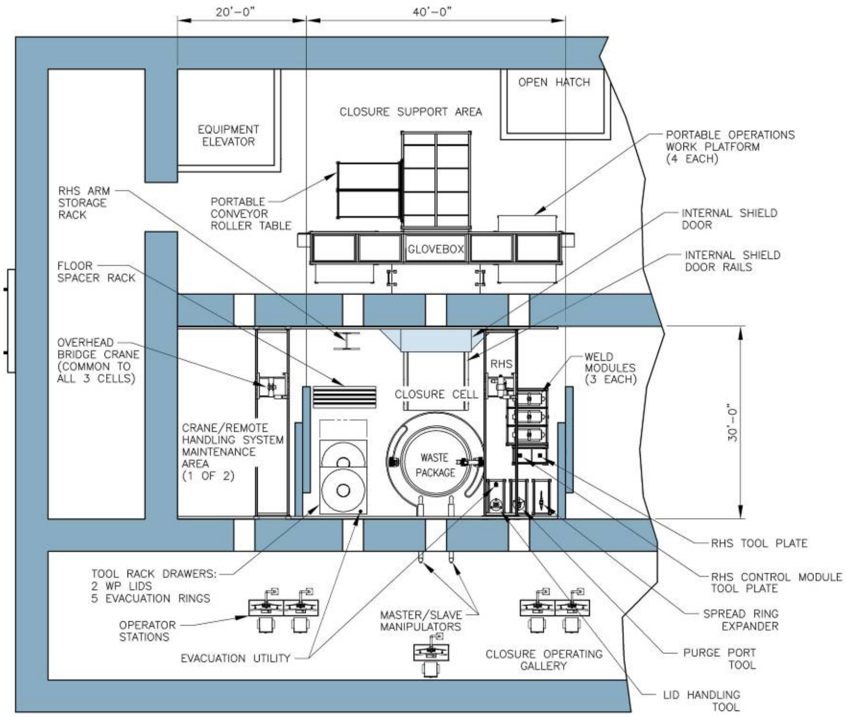

Fig. 6. A plan view of the closure cell layout and associated areas.

IV.B. Support Area

IV.B.1. Glovebox Assembly

The glovebox subsystem offers a safe and simple approach to supporting closure cell activities while protecting personnel from radiation and contamination. The design allows all material handling, servicing, maintenance, and packaging to be conducted within a contaminant confinement by personnel outside the confinement. Glovebox confinement consists of a transfer tunnel and a maintenance glovebox, as shown in Figure 7. The transfer tunnel connects a load-in area, glovebox area, transition area, and closure cell for moving materials into and out of the closure cell. Equipment is maintained and serviced in the maintenance area of the glovebox.

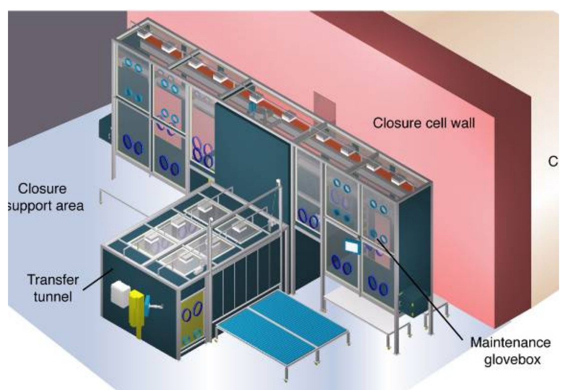

Fig. 7. The glovebox assembly is a multifunction enclosure for material movement, equipment service, and repair.

The glovebox provides the capability to transfer materials as well as service and repair equipment brought from the closure cell. A transfer cart and shield doors are installed within the transfer tunnel. It is coupled to the wall of the closure cell and directly connected to the glovebox wings that are reserved for equipment maintenance and repair operations. The wings of the glovebox include see-through windows, gloveports and gloves, and a glovebox handling system (GHS). The GHS includes an overhead bridge, trolley, and telescoping mast. The GHS, shown in Figure 8, transfers equipment between the transfer cart and the glovebox wings and articulates tools and equipment within the glovebox envelope. The controls are similar to the closure cell RHS.

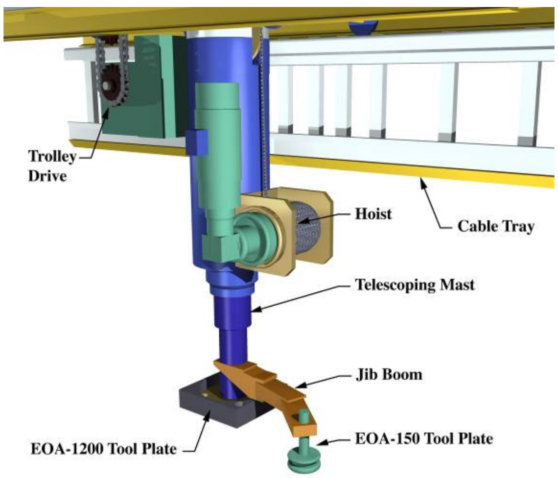

Fig. 8 An isometric view of the glovebox handling system.

Materials are introduced into the transfer tunnel through access doors and directly loaded onto the transfer cart. Differential pressure and capture velocity airflow ensure confinement is maintained during transfers. The transfer cart moves the materials from the support area into the closure cell. Materials transported on the transfer cart will be placed or received by the closure cell RHS. The transfer cart uses a linear synchronous motor that provides accurate positioning. Motor installation is configured so it remains outside of confinement and couples to the cart magnetically through the confinement floor.

Two shield doors are arranged in series in the tunnel to reduce radiation levels to as low as reasonably achievable. Only one door is opened at a time, functioning like an airlock. This sequence ensures shielding is always in place at the closure cell opening. The arrangement also creates a radiological buffer zone for monitoring equipment exiting the cell to verify the equipment does not carry any unacceptably high radiation sources.

The tunnel is configured with gloveports, windows, and equipment to support material transfers. Features also allow surveying and decontaminating the interior, collecting and counting contamination surveys, monitoring interior radiation levels, and provide personnel access to the tunnel interior. The smear counter employs unique technology to count contamination smears without transferring materials outside the glovebox or breaching confinement.

The glovebox is divided into two wings: the tool tray maintenance wing and the general maintenance wing. Maintaining the welding and inspection tool trays including replenishing weld wire, refurbishing wear surfaces and repairing weld equipment is performed in the tool tray maintenance wing. The general maintenance wing is dedicated to maintaining the balance of closure cell equipment discussed above.

The essential element of glovebox design is to design “from the inside out.” That is, it is important to design the equipment and processes to be performed inside the system first, and then design the glovebox around this information. This is the approach taken in designing the glovebox and transfer tunnel presented herein. It is also important to recognize that a glovebox contains many of the same systems of a complete facility but on a smaller scale. Incorporated in the glovebox is a fire protection system, ventilation including HEPA filtration, lighting, piping, and utilities. The design also has to address safety basis accidents, including breach of confinement and seismic concerns.

IV.C. Brief Operations Overview

Many operations take place within the closure cell. All the operations are focused around successful WP closure. The process begins when the facility places a WP into position at the floor opening. The WP has the inner lid installed prior to placing it at the closure cell access hole. A high level process is described in the following sections. The process is greatly abbreviated for the purposes of this paper.

a) The welding robots tack weld the lid into place and then complete the welds.
b) Inspections of the welds are completed.

c) Evacuation/backfill equipment is moved to the WP by the RHS and placed into position. The WP is vacuum purged and backfilled with helium, and a threaded plug is installed. The inner lid weld and plug are helium leak tested, using mass spectrometry for leakage. Following successful completion of leak detection, the test equipment is replaced into their storage locations.
d) The MSMs place a purge port cap in place over the threaded plug and hold it in position while the cap is welded to the inner lid. Visual inspection of the weld follows.
e) The middle and outer lids are introduced into the closure cell by the following sequence: 1) lids are received in the support area, 2) they are transferred into the glovebox and onto the transfer cart, 3) the transfer cart is moved into the closure cell through sequenced shield doors, and 4) the lids are lifted from the transfer cart, now in the closure cell, and transferred to storage drawers.
f) A storage drawer is opened and exposes the WP middle lid. The RHS picks it up and places it onto the WP.
g) The lid is welded to the WP then visually and eddy current inspected.
h) The outer lid is then taken from a storage drawer and placed on the WP.
i) The outer lid is welded in place, visually inspected, eddy current inspected, and ultrasonic inspected.
j) Stress mitigation is completed, and the three inspections are repeated.
k) The RHS then removes the weld tool trays and moves them onto the glovebox transfer cart. The cart delivers them to the tool tray maintenance wing inside the glovebox where they are refurbished for the next WP.

This cycle is repeated for each WP. The system is designed to complete the cycle within 44 productive hours. The effort includes documentation to address normal and off-normal situations and issues.

V. CONCLUSIONS

High-level waste and spent nuclear fuel will be sealed into standard WPs that will be placed into a repository for long-term storage. INL has designed, will produce, and will demonstrate a full-scale working prototype of a WP closure cell. Because of the highly radioactive nature of the materials, WP closure operations will be performed by remote methods.

Based on INL's successful history of design, operations, maintenance, repair, and decommissioning of over fifty nuclear test reactor and numerous hazardous chemical processing facilities, it was selected to design, construct, test, and demonstrate a WP closure cell. Experience in remote engineering design, remote material handling, process control, and remote facility operations provided the necessary background to design and demonstrate the remote handling equipment discussed in this paper.